Invasion success of exotic vines in Australia: The importance of life-history, introduction-history and ecological attributes

Carla Harris

Thesis submitted for the degree of Doctor of Philosophy at the University of Technology Sydney

July 2008

UNIVERSITY OF TECHNOLOGY SYDNEY

Certificate

I certify that this thesis has not been already submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that this thesis has been written by me. Any help that I have received in my research work as well as the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in this thesis.

Carla Harris

Acknowledgements

UTS has provided a variety of support mechanisms throughout the duration of my research that has enabled this PhD to be seen through to completion. The UTS Science Faculty provided a Postgraduate Doctoral Helix Scholarship and the Institute of Water and Environmental Research Management (IWERM) have provided a top-up for this scholarship. Without this financial assistance, my project would not have been possible.

I owe much gratitude and thanks to my supervisor, Brad Murray. I am fortunate to have had a consistently positive and supportive supervisor, which is somewhat of a rarity in PhD circles. Brad's continuing advice, conceptual input and support has played an enormous role in the journey of this thesis. Thank you for all of your encouragement and clear thinking in times of crises. I extend thanks also to Grant Hose, who played a substantial supervisory role, particularly in the initial stages of project development.

National Parks and Wildlife Services and Ballina Shire Council have also been most accommodating in enabling field sampling to occur in their areas of jurisdiction and their cooperation has been most appreciated. Thank you also to the staff at Royal Botanic Gardens (Sydney), in particular Louisa Murray, for their assistance with access to herbarium records.

Thank you to all of my field assistants: Luke Carr, Rhonda Harris, Lyndon Harris, Garreth Kyle, Damian Licari, Chris Rawson, Federico Tomasetti and Paul York. All have sacrificed their own time, braving snakes, incurring numerous slash wounds from Lawyer vine and an assortment of many other field-related bites and injuries in the pursuit of re-locating even the most elusive quadrat.

Many hands made light work with the arduous tasks of reference checking and proof-reading. In particular, thank you to Luke Carr and Anne Davidson for paying attention to detail with regard to final read-throughs and general editing of the thesis.

Over the course of my time at UTS I have formed friendships with many fellow post-graduate students from the Dept. of Environmental Sciences. Thank you to you all for your positivity, support and friendship, which as helped me through this journey more than you all will ever know.

Family and friends have also been instrumental in their patience and understanding of my 'science project', which has taken precedence over most aspects of my time over the past three and a half years. Thank you to my parents Rhonda and Lyndon for making it a priority in their lives also and to Luke for convincing me that I was doing an excellent job when I was disbelieving of the fact.

Table of contents

Table of figures

Table of Tables

Abstract

Exotic plants that become widespread and abundant (i.e. invasive) in their new range are becoming a worldwide environmental problem. Invasive plants are responsible for a number of ecological problems such as losses in biodiversity, alterations in ecosystem function and species extinctions. One of the most important steps for the successful management of invasive plants is the identification of factors that enable an introduced exotic species to become invasive. Importantly, not all introduced plants become invasive and by comparing exotic, non-invasive species to species that are invasive, it is possible to determine the suite of traits common to invasive plants that distinguishes them from non-invasive exotics. The identification of the characteristics of highly invasive species provides a greater understanding of factors contributing to their invasion success and thus contributes to the effective management of invasive plants.

In Australia, the invasion of a particular group of exotic plants, vines, is now recognised as a major threat to native biodiversity. The destructive potential of exotic vines in natural ecosystems has been recognised through the determination of invasion by exotic vines as a key threatening process by the New South Wales Scientific Committee. Yet despite the acknowledgment of the invasive potential of exotic vines, there is a paucity of information about the factors contributing to their invasion success. Thus, understanding the factors behind the invasion success of exotic vines is a research and management priority.

The primary aim of this thesis was to investigate the role that life-history, introduction-history and ecological traits play in the invasion success of exotic vines across Australia. My research examined relationships between invasion success of exotic vines and these traits at local, regional and continental spatial scales. To do this, I employed a comparative, target-area approach to distinguish differences between the attributes of non-invasive and invasive exotic vines.

Given the depauperate knowledge surrounding almost all aspects of the ecology of exotic vines in Australia, I first constructed an inventory of exotic vine species present in Australia. This important first step then enabled the process

of identifying attributes related to the invasion success of exotic vines in Australia to take place. A total of 179 species of exotic vines were identified as having established self-sustaining populations in Australia. I then performed a desktop study that focused on introduction-history attributes. I focused specifically on residence time (i.e. the length of time that each species has been present in Australia), continent of origin and reason for introduction. Minimum residence time was a significant predictor of the invasion success of exotic vines at a continental scale. That is, exotic vine species that, on average, have been present in Australia for a longer period of time were significantly more abundant than those species that had been introduced more recently. The continent of origin and reason for introduction were not significant predictors of invasion success, meaning that neither the geographic origin nor mode of introduction of exotic vine species are of consequence – in the context of these two traits, all species have the same likelihood of becoming invasive.

I then investigated relationships between life-history traits and invasion success of exotic vines across Australia. Six life-history traits were examined: seed volume, longevity, propagation, dispersal mechanism, leaf length and leaf shape. These traits were selected because they represent important aspects (or were surrogates) of a plant's life-history that have been shown to influence the invasion success of exotic plants in other ecosystems. In addition to cross-species analyses, phylogenetic regressions were performed to identify any traits that demonstrated correlated evolution with the capacity for invasion success throughout their phylogeny. I found that, in addition to residence time, annual life form, reproduction via seeds and animal dispersed seeds were traits that were positively related to the abundance of exotic vines in Australia. No phylogenetic relationships were detected between species traits and exotic vine abundance.

Local and regional scale data were collected in three littoral rainforest communities located in northern New South Wales (NSW), Australia. Littoral rainforest is an ecologically endangered community in NSW and is often found as a highly fragmented and disturbed ecosystem. As a result, littoral rainforest is vulnerable to invasion by exotic species and consequently invasive vines pose a significant threat to the health of littoral rainforest ecosystems. At the regional scale, three study regions were sampled by establishing 40 randomly allocated quadrats (each 20 x 20 m) in each study area, with an entire region representing one sampling unit, or replicate. The presence of all exotic vine species in each quadrat was recorded. At the local scale, 20 of these quadrats were sampled in more detail, with individual quadrats representing sampling units. Here, the canopy cover of each exotic vine species was recorded.

The way in which exotic vine communities are assembled may also reveal important insights into differences between non-invasive and invasive exotic vines. To explore patterns of association between exotic vine species at the regional scale, I constructed presence-absence matrices for the presence of each exotic vine species in every quadrat for each study region. I found that exotic vine species occurred together more often than would be expected by chance alone. There are several explanatory mechanisms behind these positive associations. A candidate explanation for the observed pattern is that facilitative mechanisms are operating amongst exotic vines, enabling a greater number of species to coexist. Notably, negative patterns of association (i.e. species being found together less than expected in a randomly assembled community) were never observed which adds further credence to the facilitation hypothesis.

Life-history traits were then measured at local and regional spatial scales in order to investigate how these attributes may differ among non-invasive and invasive exotic vines. For each species, I measured specific leaf area (SLA), seed mass, reproductive allocation, flowering duration and fruiting duration every season over the course of one year. Not all species produced seeds during the sampling period and therefore three species were targeted for seed trait analysis. In addition to plant life-history traits, I measured soil nitrogen, phosphorus and pH at each quadrat to explore the relationships between exotic vine abundance and soil characteristics at the local scale. Different patterns and relationships between the traits measured and exotic vine invasion success emerged across different spatial scales, highlighting the importance of accounting for the scale at which plant traits are measured. Flowering and fruiting duration emerged as being the most consistent predictors of exotic vine abundance at both local and regional scales. Invasive species had longer flowering and fruiting times than non-invasive exotic species. A negative relationship between SLA was found as predicting exotic vine invasiveness, especially at local scales, with invasive vines having significantly lower SLA than non-invasive exotics. Furthermore, negative relationships between exotic vine invasiveness and the concentration of soil phosphorous and nitrogen were also observed. These negative relationships between low soil nutrients, low SLA and invasion success are likely to be interrelated, with low soil concentrations favouring species with low SLA due to the longer leaf longevity of low SLA species, which enables vines to retain nutrients for a longer period of time than co-occurring vines with higher SLA.

In addition to measuring these traits, I also measured variation, or phenotypic plasticity, to explore the role that plasticity in a trait may have in explaining exotic vine abundance. Specifically, I measured the variance in SLA and seed mass within exotic vine species at both local and regional scales. I found that variation within SLA was a significant predictor of the abundance of some exotic vine species, yet was not related to the abundance of the most invasive species. This suggests that while trait plasticity does affect exotic vine abundances, it is not strongly related to their invasion success.

The enemy release hypothesis is a common theory proposed to explain invasion success of introduced species, whereby introduced species may increase their abundance due to a lack of natural predators in their introduced range. Field observations at my study sites identified that some species appeared to suffer greater leaf damage than others. This observation led to further field investigations of the role that insect herbivory and leaf traits may play in predicting the invasion success of invasive exotic species in comparison to those that do not achieve the same level of abundance. I predicted that, according to the enemy release hypothesis, invasive plants would have significantly less insect herbivory than non-invasive exotic vines and that leaf traits would explain these decreased herbivory rates. I measured a number of attributes including the percent of leaf damage from insect attack, type of leaf damage, leaf toughness, SLA and leaf nitrogen content. There was no relationship found between the amount of herbivore damage and invasion success of exotic vines, thus not supporting the enemy release hypothesis. I also found that, whilst there were significant differences in the leaf attributes measured, specifically leaf toughness, SLA and nitrogen content among species, they were not related to the abundance of any exotic vines in littoral rainforest. These results suggest that a reduction in herbivore damage does not explain the invasion success of exotic vines. Indeed increased herbivory for one type of insect damage was associated with species that had high abundances.

The findings of this thesis depart considerably from many other studies on plant species invasion, with unique findings between invasivness and attributes such as low SLA, large seed mass and low soil nutrients. These differences highlight that exotic vines are unlike other groups of exotic plants in many ways, which may have important consequences for the ecosystems they invade. I suggest that these dissimilarities are primarily a function of the structural differences of vines to other plant functional groups, providing invasive vines with a number of ecological advantages.